International Tokamak Physics Activity (ITPA)

discussion facilitated by Ned Sauthoff

Acknowledgements:

D J Campbell and M Shimada

ITPA TG Chairs/Co-chairs, members and friends

ITPA International Tokamak Physics Activity

Outline

- **Charter, structure, and related actions**
- **Updating the Tokamak Physics Basis**
- **Topical Areas**
  - US membership
  - High-priority R&D
  - Joint Experiments
- **Planned ITPA meetings and the future of the ITPA**

ITPA International Tokamak Physics Activity

Charter

“The International Tokamak Physics Activity (ITPA) aims at cooperation in development of the physics basis for burning tokamak plasmas.”

ITPA International Tokamak Physics Activity

Chartered activities

- **"The ITPA shall consist in providing :**
  - validated experimental data according to an agreed format;
  - analyzed results of experiments to advance understanding of fusion plasma physics;
    the organization, management, and updating of qualified databases;
  - theoretical models and simulation results to explain and reproduce experimental results;
  - studies of fusion plasma performance in burning plasma tokamak devices, such as ITER; and
  - identification and resolution of key diagnostics issues which might arise both in plasma control and in analysis of a burning plasma experiment, such as ITER."

ITPA International Tokamak Physics Activity

Related Actions

- **"Joint Experiments" through the IEA agreements are targeted at increasing the effectiveness of the implementation of high-priority R&D**
- **Stellarator participation**
  - The stellarator community has been added to the ITPA, with one stellarator representative added to each topical group
  - The objective of the ITPA remains developing the physics basis for a burning tokamak plasma
- **The ITPA figures prominently in the ITER Transitional Activities**
- **China has requested to be added to the ITPA**

ITPA International Tokamak Physics Activity

Topical Group Structure

- **Confinement Database and Modelling**
- **Transport and Internal Transport Barrier**
- **Pedestal and Edge Physics**
- **Divertor and Scrape-off Layer**
- **MHD, Disruptions and Control**
- **Steady-state Operation and Energetic Particles***
- **Diagnostics**

* “Integrated steady-state operation” has become a primary area of focus, focused in the Steady-state Operation and Energetic Particles topical group

ITPA International Tokamak Physics Activity

Advances in the tokamak physics basis (1 of 2)

- achievement of good H-mode confinement at $n \sim n_G$;
- development of alternative H-mode regimes with ITER-relevant performance at higher q_{95};
- demonstration of enhanced helium exhaust by elastic scattering;
- improvements in theory-based confinement validation and projection, confirming scaling-based predictions of fusion amplification factor;
- further progress in elucidating the coupling between plasma edge conditions and core confinement;
- improved understanding of ELM physics, developments in ELM mitigation techniques and alternative ELM regimes with high confinement;
- demonstration of active feedback control of NTMs by ECCD and resultant improvement in the sustainable β values;
- demonstration of increased β-limit by stabilization of RWM;
- demonstration of disruption mitigation by strong impurity puffing;

ITPA International Tokamak Physics Activity

Advances in the tokamak physics basis (2 of 2)

- expansion of operating space for quasi-steady-state sustainment of ITBs and demonstration of realtime control of ITBs;
- demonstration of suppression of impurity accumulation inside ITBs by central heating;
- progress towards long non-inductive operation of tokamak plasmas;
- substantial developments in real-time control schemes;
- improvements in technology of heating and current drive systems (N-NBI, ECRH, etc.) and exploitation in tokamak experiments;
- continued progress in diagnostic measurement capability (e.g., collective scattering from energetic particles).

ITPA International Tokamak Physics Activity

Updating the Tokamak Physics Basis

- **Due to this increased understanding since the finalization of the ITER Physics Basis (~5 years ago),**

  the ITPA Coordinating Committee has requested that the Topical Groups prepare a sequel to the ITER Physics Basis:

  "The Tokamak Physics Basis"

  - aimed at documenting the physics basis for burning plasma experiments
  - planned for finalization ~1/04
  - topical groups are expressing concerns about the schedule

- **Nermin Uckan and John Wesley will serve as the 2 US editors**

ITPA International Tokamak Physics Activity

Outline

- **Charter and structure**
- **Updating the Tokamak Physics Basis**
- **Topical Areas**
  - US membership
  - High-priority R&D
  - Joint Experiments
- **Planned ITPA meetings and the future of the ITPA**

ITPA International Tokamak Physics Activity

Confinement Database and Modelling: US members

- **Members of the International Group:**
  - Wayne Houlberg (ORNL), chair, US Leader
  - Jim Deboo (GA), US Co-leader
  - Stan Kaye (PPPL)
  - Joe Snipes (MIT)
  - Masunari Murakami (ORNL)

- **Members of the US Group:**
  - Tom Casper (LLNL)
  - Tom Carlstrom (GA)
  - Lynda Lodestro (LLNL)
  - Glenn Bateman (Lehigh)
  - Dale Meade (PPPL)
  - Arnold Kritz (Lehigh)
  - Martin Greenwald (MIT)

ITPA International Tokamak Physics Activity

Confinement Database and Modelling: High-priority R&D

- Examine the effects of inside and vertical pellet launch on the density profile, ELMs, and other aspects of confinement to clarify the impact of pellet injection on performance and control of burning plasmas.
- Examine isotopic effects on confinement on the same machine.
- Confinement scaling experiments with β need to be extended over a broader range of ρ^* and ν^*.
- More high resolution pedestal data is needed.

ITPA International Tokamak Physics Activity

Confinement Database and Modelling: Joint Experiments

Proposal Title	Devices
Effects of inside and vertical pellet launch	AUG, DIII-D, FTU, JET, JT-60U, Tore Supra
□ scaling of confinement in ELMy H-modes	All available devices, DIII-D, JET, *NSTX , AUG, JT-60U*
Improving the condition of Global ELMy H-mode and Pedestal databases	All available devices

ITPA International Tokamak Physics Activity

Transport and Internal Transport Barrier: US members

- **Members of the International Group:**
  - Ed Doyle (UCLA), chair, US Leader
  - Ed Synakowski (PPPL), US Co-leader
  - John Rice (MIT)
  - John Kinsey (Lehigh)
  - Punit Gohil (GA)
  - Dave Mikkelson-Stellarator (PPPL)

- **Members of the US Group:**
  - Michael Kotschenreuther (Texas)
  - Catherine Fiore (MIT)
  - Larry Baylor (ORNL)
  - Wendell Horton (Texas)
  - Chuck Greenfield (GA)
  - T.S. Hahm (PPPL)
  - Bill Nevins (LLNL)

ITPA International Tokamak Physics Activity

Transport and Internal Transport Barrier: High-priority R&D

- **Improve experimental characterization and understanding of critical issues for reactor relevant regimes with ITBs, including:**
  - Continue to optimize and improve steady state and hybrid operation demonstration discharges
  - Obtain higher performance with Te~Ti,
  - Impurity accumulation (low- and high-Z)
  - Compatibility with edge conditions (ELMs, density..)
- **Contribute relevant data to the international experimental ITB database; utilize database to test predictive theory-based models and ITB formation conditions.**
- **Study experimental plasma results that challenge understanding of ion transport, such as flat core profiles, electron-ion coupling, etc.**
- **Test simulation predictions via comparisons to measurements of turbulence characteristics, code-to-code comparisons and comparisons to transport scalings.**

ITPA International Tokamak Physics Activity

Transport and Internal Transport Barrier: Joint Experiments

Proposal Title	Devices
Development of hybrid scenario demonstration discharges	AUG, DIII-D, JET, JT-60U
Development of steady-state demonstration discharges	AUG, DIII-D, JET, JT-60U
High performance operation with $T_e \sim T_i$	*AUG, DIII-D, JET, JT-60U*
ITB operation with no external momentum input	AUG, C-Mod, DIII-D, JET, JT-60U
Improved physics understanding of QDB/QH-mode operation	AUG, DIII-D, JET, *JT-60U*
Improved understanding of □-limits with ITB operation	AUG, *DIII-D, JET, JT-60U, NSTX*
Development of real-time profile control capabilities	AUG, DIII-D, JET, Tore Supra
Dimensionally similar ITB scaling experiments	AUG, JET
Simulation and modelling support for T-10 turbulence studies	T-10

ITPA International Tokamak Physics Activity

Pedestal and Edge Physics: US members

- **Members of the International Group:**
  - Tom Osborne (GA), US Leader
  - Amanda Hubbard (MIT), US Co-leader
  - Jim Drake (Maryland)
  - Tom Rognlien (LLNL)
  - Micky Wade (ORNL)

- **Members of the US Group:**
  - Xueqaqio Xu (LLNL)
  - Phil Snyder (GA)
  - Rich Groebner (GA)
  - Rip Perkins (PPPL)

ITPA International Tokamak Physics Activity

Pedestal and Edge Physics: High-priority R&D

- **Improve predictive capability of pedestal structure through profile modelling.**
- **Construct physics-based and empirical scaling of pedestal parameters.**
- **Improve predictive capability for ELM size and frequency and assess accessibility to regimes with small or no ELMs.**

ITPA International Tokamak Physics Activity

Pedestal and Edge Physics: Joint Experiments

Proposal Title	Devices
Understanding of pedestal characteristics through dimensionless experiments	JET, JT-60U
JET/DIII-D pedestal similarity studies	DIII-D, JET
Comparative MHD analysis and predictive modelling of type I and type II ELMy H-mode	*AUG,* JET, JT-60U
Stability analysis with improved edge treatment	AUG, DIII-D, JT-60U
Dimensionless identity experiments with JT-60U type II ELMy H-modes in DIII-D	*DIII-D, JT-60U*
Impact of ELMs on the pedestal and SOL (effect of aspect ratio)	*AUG, DIII-D, MAST, NSTX*
Parameter similarity studies (L-H transition, EDA)	AUG, C-Mod, *JET*
Parameter similarity studies Quiescent H-mode regimes)	AUG, DIII-D, JET, *JT-60U*

ITPA International Tokamak Physics Activity

Divertor and Scrape-off Layer: US members

- **Members of the International Group:**
  - Bruce Lipschultz (MIT), US Leader
  - Gary Porter (LLNL), US Co-leader
  - Dennis Whyte (U. Wisconsin)
  - Sergei Krasheninnikov (UCSD)
  - Peter Stangeby (LLNL/GA)
- **Members of the US Group:**
  - Rajesh Maingi (ORNL)
  - Ali Mahdavi (GA)
  - Daren Stotler (PPPL)
  - John Hogan (ORNL)

ITPA International Tokamak Physics Activity

Divertor and Scrape-off Layer: High-priority R&D

- **Understand the effect of ELMS/disruptions on divertor and first wall structures.**
- **Tritium retention & the processes that determine it.**
- **Improve understanding of SOL plasma interaction with the main chamber.**
- **Better prescription of SOL perpendicular transport coefficients and boundary conditions for input to BPX modelling.**

ITPA International Tokamak Physics Activity

Divertor and Scrape-off Layer: Joint Experiments

Proposal Title	Devices
Scaling of type I ELM energy loss	*DIII-D, JET, JT-60* U and others
Tritium codeposition	AUG, C-Mod, DIII-D, JET, JT-60U, TEXTOR, Tore Supra
Scaling of radial transport	AUG, C-Mod, DIII-D, JET, JT-60U, MAST, TCV
Disruptions and effect on materials choices	AUG, DIII-D, JET, JT-60U, TEXTOR, TCV
Role of Lyman absorption in the divertor	C-Mod, JET
Parallel transport in the SOL	*AUG, DIII-D,* C-Mod, JET, JT-60U

ITPA International Tokamak Physics Activity

MHD, Disruptions and Control: US members

- **Members of the International Group:**
  - Ted Strait (GA), US Leader
  - Steve Jardin (PPPL), US Co-leader
  - Robert Granetz (MIT)
  - John Wesley (GA)
  - Gerry Navratil (Columbia)
  - Ed Lazarus-Stellarator (ORNL)

- **Members of the US Group:**
  - Chris Hegna (Wisconsin)
  - Eric Frederickson (PPPL)

ITPA International Tokamak Physics Activity

MHD, Disruptions and Control: High-priority R&D

- MHD stability analysis of H-mode edge transport barrier under Type I and tolerable ELM conditions.
- NTMs: island onset threshold, stabilisation of (3,2) and (2,1) NTM islands at high-β and β recovery, possible operation with benign NTMs (FIR, seed island control); identify requirements for reactor plasmas.
- RWMs: analysis, experimental verification of control, role of plasma rotation and error fields, control system requirements for diagnostics.
- Construction of new disruption DB including conventional and advanced scenarios and heat loads on wall/targets.
- Development of disruption mitigation techniques, particularly noble gas injection.

ITPA International Tokamak Physics Activity

MHD, Disruptions and Control: Joint Experiments

Proposal Title	Devices
Pressure and size scaling of gas jet penetration for disruption mitigation	*AUG, C-Mod, DIII-D, JET, JT-60U*
Joint experiments on resistive wall mode physics	AUG, DIII-D, JET, *NSTX*
Joint experiments on neoclassical tearing modes (including error field effects)	AUG, DIII-D, JET
Neoclassical tearing mode physics - aspect ratio comparison	*AUG, DIII-D, MAST, NSTX*
Comparison of sawtooth control methods for neoclassical tearing mode suppression	AUG, *DIII-D* , JET
Error field sideband effects for ITER	*DIII-D, JET*

ITPA International Tokamak Physics Activity

Steady-state Operation and Energetic Particles: US members

- **Members of the International Group:**
  - Cynthia Phillips (PPPL), US Leader
  - Ron Prater (GA), US Co-leader
  - Paul Bonoli (MIT)
  - Cary Forest (Wisconsin)
  - William Heidbrink (UCI)

- **Members of the US Group:**
  - Doug Darrow-EP (PPPL)
  - Tim Luce (GA)
  - Boris Breizman (Texas)
  - Don Batchelor (ORNL)
  - Raffi Nazikian (PPPL)
  - Nikolai Gorelenko (PPPL)
  - Dave Swain (ORNL)
  - M. Zarnstorff (PPPL)

ITPA International Tokamak Physics Activity

Steady-state Operation and Energetic Particles: High-priority R&D

- **Multi-machine assessment of candidate steady state and hybrid scenarios.**
- **Install steady state scenario development data base.**
- **Explore and develop plasmas with very high bootstrap content.**
- **H&CD code benchmarking on FWCD, NBCD, LHCD and ECCD.**
- **Start assessment of reversed shear operational space: modelling codes for EP collective modes and experiments including mainly quantitative measurements.**
- **Assess effects on EP of proposed q-profiles for steady state and hybrid scenarios.**

ITPA International Tokamak Physics Activity

Steady-state Operation and Energetic Particles: Joint Experiments

Proposal Title	Devices
Preparation of ITER steady-state scenario	AUG, DIII-D, JET, JT-60U
Preparation of ITER hybrid scenario	AUG, DIII-D, JET, JT-60U

ITPA International Tokamak Physics Activity

Diagnostics: US members

- **Members of the International Group:**
  - Dave Johnson (PPPL), US Leader
  - Rejean Boivin (GA), US Co-leader
  - Tony Peebles (UCLA)
  - George McKee (Wisconsin)
  - Glenn Wurden (LANL)

- **Members of the US Group:**
  - Tony Leonard (GA)
  - Ray Fisher (GA)
  - Ken Young (PPPL)

ITPA International Tokamak Physics Activity

Diagnostics: High-priority R&D

- Review requirements for measurements of neutron/a-particle source profile and assessment of possible methods of measurement.
- Determination of MINIMUM requirements necessary to support advanced tokamak operation and control, and assessment of the possible measurement techniques.
- Assess impact of RIEMF on magnetic measurements and perform improved measurements on prototype coils.
- Determination of life-time of plasma facing mirrors used in optical systems.
- Development of methods of measuring the energy and density distribution of confined and escaping a-particles.

ITPA International Tokamak Physics Activity

Diagnostics: Joint Experiments

Proposal Title	Devices
Diagnostic First Mirrors	All available devices
Measurement of q(r)	All available devices
Confined and escaping □-particles and other fast ions	All available devices
Measurements needed to support advanced tokamak operation	All available devices
Development of radiation resistant components and ITER/reactor relevant measurement techniques	All available devices

ITPA International Tokamak Physics Activity

The facilities have responded well to these requests for joint experiments

Proposal Title	Devices	C-Mod: FY03 Run Days Completed	C-Mod: FY03 Run Days planned	DIII-D
Effects of inside and vertical pellet launch	AUG, DIII-D, FTU, JET, JT-60U, Tore Supra			
□ scaling of confinement in ELMy H-modes	All available devices, DIII-D, JET, *NSTX , AUG, JT-60U*		1	1
Improving the condition of Global ELMy H-mode and Pedestal databases	All available devices	3	1	
Development of hybrid scenario demonstration discharges	AUG, DIII-D, JET, JT-60U			2
Development of steady-state demonstration discharges	AUG, DIII-D, JET, JT-60U			~4
High performance operation with Te ~ Ti	*AUG, DIII-D, JET, JT-60U*	1	2	0 to 1
ITB operation with no external momentum input	AUG, C-Mod, DIII-D, JET, JT-60U	8	5	
Improved physics understanding of QDB/QH-mode operation	AUG, DIII-D, JET, *JT-60U*			3
Improved understanding of □-limits with ITB operation	AUG, *DIII-D, JET, JT-60U, NSTX*			2 to 3
Development of real-time profile control capabilities	AUG, DIII-D, JET, Tore Supra			
Dimensionally similar ITB scaling experiments	AUG, JET			
Simulation and modelling support for T-10 turbulence studies	T-10			
Understanding of pedestal characteristics through dimensionless experiments	JET, JT-60U	1	2	
JET/DIII-D pedestal similarity studies	DIII-D, JET			1
Comparative MHD analysis and predictive modelling of type I and type II ELMy H-mode	*AUG,* JET, JT-60U			
Stability analysis with improved edge treatment	AUG, DIII-D, JT-60U		1	study to be completed
Dimensionless identity experiments with JT-60U type II ELMy H-modes in DIII-D	*DIII-D, JT-60U*			0
Impact of ELMs on the pedestal and SOL (effect of aspect ratio)	*AUG, DIII-D, MAST, NSTX*			0.5
Parameter similarity studies (L-H transition, EDA)	AUG, C-Mod, *JET*	1	1	
Parameter similarity studies Quiescent H-mode regimes)	AUG, DIII-D, JET, *JT-60U*			0.5

ITPA International Tokamak Physics Activity

The facilities have responded well to these requests for joint experiments

Proposal Title	Devices	C-Mod: FY03 Run Days Completed	C-Mod: FY03 Run Days planned	DIII-D
Scaling of type I ELM energy loss	*DIII-D, JET, JT-60U* and others			0.5
Tritium codeposition	AUG, C-Mod, DIII-D, JET, JT-60U, TEXTOR, Tore Supra		1	2
Scaling of radial transport	AUG, C-Mod, DIII-D, JET, JT-60U, MAST, TCV		1	
Disruptions and effect on materials choices	AUG, DIII-D, JET, JT-60U, TEXTOR, TCV		1	
Role of Lyman absorption in the divertor	C-Mod, JET			
Parallel transport in the SOL	*AUG, DIII-D,* C-Mod, JET, JT-60U		1	1
Pressure and size scaling of gas jet penetration for disruption mitigation	*AUG, C-Mod, DIII-D, JET, JT-60U*			1
Joint experiments on resistive wall mode physics	AUG, DIII-D, JET, *NSTX*			0.5
Joint experiments on neoclassical tearing modes (including error field effects)	AUG, DIII-D, JET		1	1
Neoclassical tearing mode physics - aspect ratio comparison	*AUG, DIII-D, MAST, NSTX*			0
Comparison of sawtooth control methods for neoclassical tearing mode suppression	AUG, *DIII-D* , JET			1
Error field sideband effects for ITER	*DIII-D, JET*			1
Preparation of ITER steady-state scenario	AUG, DIII-D, JET, JT-60U			~4
Preparation of ITER hybrid scenario	AUG, DIII-D, JET, JT-60U			2
Diagnostic First Mirrors	All available devices			
Measurement of q(r)	All available devices	1.5	2	
Confined and escaping a-particles and other fast ions	All available devices			
Measurements needed to support advanced tokamak operation	All available devices			
Development of radiation resistant components and ITER/reactor relevant measurement techniques	All available devices			

ITPA International Tokamak Physics Activity

2003 ITPA Meetings

title	date	location	joint session	Remarks/local organiser
Co-ordinating Committee Meeting	2-3 Oct. 2003	General Atomics		approved
Diagnostics	17-21 Feb. 2003	Padua, Italy		approved
	14-18 July 2003	Moscow (15-18 July)	14 July : Control Workshop	EPS(7-11 July, St. Petersburg)
MHD, Disruption and Control	14-16 July 2003	St. Petersburg	14 July : Control Workshop, divertor TG	EPS(7-11 July, St. Petersburg)
Steady State Operation and Energetic Particles	14-16? July 2003	St. Petersburg	14 July : Control Workshop	EPS(7-11 July, St. Petersburg)
	8-10 October 2003	General Atomics		in conjunction with TM on Energetic Particles on 6-8 October
ITB and Transport	8-12 Apr. 2003	Ioffe institute, St, Petersburg, Russia	CDBM	approved/Sergei Lebedev
	29 Sept.-3 Oct., 2003?	General Atomics	CDBM	H-mode WS (24-26 Sept., GA)
Confinement Database and Modeling	8-11 April	Ioffe Institute, St. Petersburg	ITB and Transport	approved/Sergei Lebedev
	29 Sept.-3? Oct. 2003	General Atomics	ITB and Transport	H-mode WS (24-26 Sept., GA)
Pedestal and Edge	14-17 April 2003	JAERI		approved/T. Hatae
	29 Sept.-3? Oct. 2003	General Atomics		H-mode WS (24-26 Sept., GA)
Sol and Divertor	14-17 or 18 July 2003	St. Petersburg	14 July : Control Workshop, MHD TG	EPS(7-11 July, St. Petersburg)
	November 2003	Naka		

Department of Energy
Germantown, MD 20874-1290

Dr. David Campbell, Chair
International Tokamak Physics Activity
European Fusion Development Agreement
Close Support Unit - Garching
Max-Planck-Institut für Plasmaphysik
Boltzmannstr. 2
D-85748 GARCHING bei München

Dear Dr. Campbell:

I am glad to inform you that the Office of Fusion Energy Sciences agrees to extend the duration of International Tokamak Physics Activity (ITPA) for two years beyond its current expiration date of July 2003.

I have been following the work of ITPA and I am very pleased with its progress and achievements since its inception only a year ago. A large number of U.S. researchers are actively involved with the ITPA Topical Physics Groups, and they have been enjoying working with their international colleagues on the burning plasma physics issues. Your recent meeting at MIT to coordinate joint experiments among the major world tokamaks and use of IEA Implementing Agreements to implement ITPA proposals is a good example of the value of ITPA to the world tokamak program.

Thank you for your efforts in making ITPA a success.

Sincerely,

N. Anne Davies
Associate Director
for Fusion Energy Sciences
Office of Science

c.c. Erol Oktay
Ron Stambaugh
Ned Sauthoff

ITPA International Tokamak Physics Activity

Summary

- The ITPA has re-targeted its activity to include “Steady-State Operations”, including AT scenarios of special interest to the US community
- “Joint Experiments” through the IEA agreements will likely increase the effectiveness of the implementation of high-priority R&D
- Stellarator participation is beginning
- The ITPA figures prominently in the ITER Transitional Activities
- US participation is mutually beneficial for the burning plasma projects and for the participants